

APPLICATION FOR UNITED STATES LETTERS PATENT

for

METHOD FOR SEALING ELECTROLUMINESCENCE DISPLAY DEVICES

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METHOD FOR SEALING ELECTROLUMINESCENCE DISPLAY DEVICES

BACKGROUND

[0001] The present disclosure relates generally to organic electroluminescence display elements, and more particularly to the sealing methods of the packages for encapsulating the display elements used in electro-optical display devices and the like.

[0002] An electroluminescence (EL) element is a light emitting device which utilizes electric field light emission of solid fluorescent substance or phenomenon called electroluminescence. The luminous material layers of an EL device is commonly applied in the backlight of liquid crystal, flat panel, electro-optical displays which may be either transmissive, reflective and/or transfective. Certain advanced technology EL elements such as organic light emission diodes (OLEDs) has migrated from the use of inorganic, to the use of organic polymer material compound layers as the luminous material layers of the devices. The use of the organic polymer layers offer improvements to the display devices' display performance, operational efficiencies, package sizing/portability, as well as reduction in power and voltage requirements.

[0003] Fig.1 is a cross-sectional view of a single, typical OLED pixel to briefly illustrate the basic structural components. The OLED pixel is fabricated on top of a transparent, translucent substrate material 102. A transparent conductive anode layer 104, typically comprised of indium tin oxide (ITO), is formed on the substrate 102. The first organic polymer layer 106 used as the electron hole transfer layer of the emitting pixel, is deposited upon the ITO 104 layer. The second organic polymer layer 108 used as the actual pixel luminous/emission layer is then deposited upon the first organic polymer layer 106. It is noted that for further discussion within this disclosure, that all references to the EL organic polymer layer implies actual reference to the combination of the two organic polymer layers, 106 and 108. A cathode layer 110, usually comprised of an aluminum-based metal compound, is then formed on top of the second organic polymer layer 108 to complete the basic OLED pixel. In addition, a protective dielectric material layer or structures 112 may also be deposited on top of the cathode layer 110. It is understood that a plurality of the OLED pixels are arranged to provide a display panel. What is not shown in this Fig. 1 is a transistor that drives this OLED pixel integrated therewith, and there may be other materials such as dielectric materials or passivation materials (such as silicon nitride SiN_x) placed in various locations of the display panel for providing a fully functional display device.

[0004] Organic EL elements are much more sensitive to degradation issues related to ambient environment conditions such as water moisture, than inorganic EL elements. Such degradation may lead to performance loss, operational instability, poor color/emission accuracies, as well as shortened operational life. Specifically, water moisture may cause undesired crystallization and formation of organic solids, undesired electrochemical reactions at the electrode-organic layer interfaces, corrosion of metals and the undesired migration of ionic species. To minimize such degradation mechanisms, the organic EL elements must be well sealed, properly encapsulated to prevent moisture migration to the active EL display elements. Typical encapsulation methods utilize a shield substrate covering the entire organic polymer areas with an adhesive sealant used to seal the shield substrate to the device substrate layer 102. For LCD as well as LED devices, depending on the technology, the shield substrate may contain various color filters to produce necessary red, yellow, or blue emission light.

[0005] Fig. 2 is a top view of a typical organic EL device to illustrate the application of the shield substrate and adhesive sealant to encapsulate the display panel. The device substrate 102 is shown covered with the encapsulation shield substrate 202. The shield substrate 202 may be a color filter, and covers the entire organic EL device with continuous lines of adhesive sealant 204 located

on the device substrate 102 along the same directions as the length and width perimeters of the EL display device. The shield substrate 202 is attached directly to the device substrate 102 utilizing the adhesive sealant 204 to encapsulate the EL display device. As will be better shown in Figs. 3a and 3b below, the encapsulation seal is accomplished primarily using a sealant between the bottom surface of the shield substrate 202 and top surface of the device substrate 102. It is further noted that since in areas where the device substrate and the shield substrate are sealed together, there are no cathode and anode material, but the top two layers of the device substrate may typically be the organic polymer layer and a passivation layer underneath.

[0006] Figs. 3a and 3b illustrate two additional views of the typical display device as described by Figs. 1 and 2. Fig. 3a is a top view illustrating an openings for exposing a portion of the device substrate 302, where the sealant is placed, and locations of various organic polymer areas 304 in the relative center portion of the display device. In order to place a sealant between the device substrate 302 and the shield substrate, the organic polymer material on top of the passivation layer in the opening 302 is removed so that the substrate having the passivation layer 302 is exposed. When the sealant is put in the opening 302, certain portion of the sealant will rest on the neighboring and unremoved organic polymer material 304, and the sealant width or sealant gap is shown

marked by the distance g confined by the two vertical dotted lines. The area with the sealant gap g may be referred to as the sealant region. The horizontal dotted line marked x shows the plane by which the cross-sectional view of this portion of the EL device is shown by Fig. 3b.

[0007] Fig. 3b illustrates the cross sectional view showing the relative locations of the device substrate 302, the organic polymer area 304, the spacers 306 formed on top of the organic polymer area 304, and the encapsulation shield substrate 308. The gap area 310 enclosed by the top surface of the device substrate 302, the sides of the organic polymer areas 304, and the bottom surface of the shield substrate 308 represent the volume where the adhesive sealant is applied to complete the seal for the encapsulation of the EL display device. The spacers 306 are placed to maintain the gap between the organic polymer area 304 and the shield substrate 308.

[0008] The irregular gap volume 310 shown in Fig. 3b and its relative long sealant gap of the applied adhesive sealant may induce certain issues with the encapsulation and the performance of the display device. The irregular volume 310 featuring irregular gaps between the top and bottom sealing surfaces may allow incidences and conditions for poor seals to occur. Voids may occur within the applied sealant such that sealant may be poor or degrade in time. The

thickness of the sealant to cover the vertical distance from the device substrate 302 to the shield substrate 308 may be difficult to apply in a precise, controlled manner. More specifically, as shown, the sealant sits partially on both organic polymer material areas on both sides, thereby creating two "shoulders" 312.

With these shoulders, the sealant must be well centered to avoid undesired "shoulder tilting," which may cause undesired effects upon the performance of the display device. Such defects as mura, systematic deviations or blemishes that causes irregular luminosity variations, may manifest as striped/banded defects originating from the tilted gap seal regions.

[0009] The large volume and thickness of the applied sealant may also lead to opportunities for sealant adhesion and peeling issues. Film stress properties and surface conditions of the sealant surfaces particularly, the device substrate 302, may be non-optimum or subsequently change during device operational life such that the adhesion to the sealant becomes degraded and the sealant begins to detach and peel from the surface. Such peeling will lead to the loss of the encapsulation integrity.

[0010] What is desirable is an improved method for the sealing of the encapsulating shield substrate onto the organic EL display devices.

SUMMARY

[0011] A method is disclosed for encapsulating at least one display device.

According to one example, a plurality of parallel openings are formed in a first material layer on a first substrate to expose a second material layer underneath.

A predetermined sealant is placed thereon to form a sealant region perpendicular to the openings for attaching a second substrate, wherein the sealant contacts the first material layer and the second material layer through the openings for encapsulating the display device between the first and second substrates.

[0012] According to another example, a sealant region having one or more openings having a predetermined pattern is formed by removing portions of a first material layer on a first substrate to expose a second material layer underneath. A predetermined sealant is placed in the openings for attaching a second substrate with the first substrate, wherein the sealant in the openings is balanced along an axis of the sealant region.

[0013] These and other aspects and advantages will become apparent from the following detailed description, taken in conjunction with the accompanying drawings, illustrating by way of example the principles of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Fig. 1 illustrates a cross-sectional view of a single conventional OLED pixel.

[0015] Fig. 2 illustrates a top view of a typical organic EL display device with an encapsulation shield substrate sealed thereon.

[0016] Figs. 3a and 3b are top and cross-sectional views of a portion of the organic EL display device with an encapsulation shield substrate sealed via conventional method.

[0017] Figs. 4a-4c are top and cross-sectional views of an organic EL display device with an encapsulation shield substrate sealed therewith according to one example of the present disclosure.

[0018] Fig. 5 is a detailed top view of a sealant region of the organic EL display device according to another example of the present disclosure.

[0019] Figs. 6a-6c are top views of several pattern variations of the sealant region of the organic EL display device according to examples of the present disclosure.

DESCRIPTION

[0020] The present disclosure describes an improved method for the effective sealing of an encapsulating shield substrate over the organic EL display panel. The disclosed method is less prone to the reliability and integrity issues experienced with the conventional sealing method. Irregular vertical gaps are avoided to help reduce the formation of voids in the sealant regions. The required width of the sealant in an opening between two organic polymer areas is reduced to help minimize tilt issues and mura defects from the sealed shield substrate. Such improved method would be easily implemented into existing fabrication operations and processes with minimal impact of additional costs and required processes. This disclosed more reliable encapsulation seal will lead to higher production yields for the organic EL display devices, as well as higher integrity and longer operational life of the said devices.

[0021] Figs. 4a-4c illustrate an example of the shield substrate sealing method according to one example of the present disclosure. Fig. 4a is a top view of the sealant region of an organic EL display device while Fig. 4b and 4c are sectional views thereof. As shown, instead of a continuous organic polymer layer, the organic polymer layer 404 has stripes of narrow openings 402 processed thereon, which may be referred to as a slit structure. This can be done by masking out

certain areas from polymer formation, provided that this slit structure does not affect the need of the organic polymer for the active pixel regions. The sealant region 403 is located perpendicular to the openings 402. As such, in selected locations of the openings 402, the exposed substrate areas can receive sealant.

[0022] In this example, the sealant is going to be placed in the aligned sealant region defined by the two vertical dotted lines having a width of g . The width of the two shown exposed device substrate areas 402 are marked on as $L1$ and $L3$, respectively. The distance between two adjacent exposed device substrate regions 402, which is the organic polymer layer, is also marked, as $L2$. It is understood that $L1$ and $L3$ may not need to be of the same size. Since the function of these openings is to allow the sealant to rest on the substrate, they do not have to have uniform width. Optimum $L1$ and $L3$ widths of these two exposed regions for sealant application may be dependant upon the distance $L2$ between the two regions.

[0023] Fig. 4b is the cross-sectional view of the portion of the organic EL display device corresponding to the one shown in Fig. 4a along the plane defined by the horizontal dotted line marked as x . Fig. 4b illustrates the device substrate 402, the organic polymer layer 404, the spacers 406, and the shield substrate 408. The volume 410 is the sealant deposited on top of the organic polymer layer 404.

[0024] Fig. 4c is the cross-sectional view of another portion of the organic EL display device corresponding to the one shown in Fig. 4a along the plane defined by the horizontal dash line marked as x' in Fig. 4a. Fig. 4c illustrates the device substrate 402 and the shield substrate 408 without the organic polymer layer 404 in between. The sealant 410 is formed directly between the device substrate 402 and the shield substrate 408. It is noted that although the sealant region 410 illustrated in this Fig. 4c has clearly defined side walls 412, it is understood that in practice, since there is nothing that confines the sealant, the side walls are naturally formed and may not have a flat surface. This does not affect the function of the sealant as the sealant peeling issues has nothing to do with how smooth the side walls are. It is further noticed by comparing Figs. 4b and 4c, the volume of the sealant used in the sealant region on top of the organic polymer layer is less than the sealant region on top of the device substrate since openings for receiving the sealant are deeper through the organic polymer layer in Fig. 4c.

[0025] It is by this method of using narrow stripes of openings in the organic polymer layer that are perpendicular to the aligned sealant region, the sealant makes sufficient contact with the areas underneath. As shown in either Fig. 4b or 4c, there is no "shoulders" for the sealant, as it is either completely on the organic polymer layer or on the substrate layer, therefore, it maintain relatively even contact surfaces with the organic polymer layer or the device substrate

layer such that no "tilting" is likely to happen, thereby minimizing the opportunity for sealant peeling.

[0026] Fig. 5 illustrates a top view of a sealant region with a predetermined pattern for encapsulating the shield substrate over the organic EL display device in accordance with another example of the present disclosure. Fig. 5 shows that portions of the organic polymer region 502 is removed to have an opening 504 of a saw teeth pattern. Although the pattern is referred to as a saw teeth pattern here, as it is illustrated, the opening is formed by small segments that are either parallel or perpendicular to each other. Since semiconductor manufacturing deals largely with aligned lines of a perpendicular or parallel relation, forming an opening or openings like this is not troublesome. It is further noticed that the segments may have different widths as long as the sealant is distributed in a balanced manner. The outer borders of the region for placing the sealant is still roughly defined by the vertical dotted lines with a width of g . In order to avoid the cell gap problem, the predetermined pattern for the opening 504 is designed to reduce the gap between the organic polymer areas as indicated by the distance between pairs of arrows. As it is clearly illustrated, although the outer borders of the sealant region may be still as wide as the distance g , there actually does not exist in any particular location a gap that is as wide as the distance g . In addition, with this sealant pattern, the sealant material is relatively evenly

distributed over the two sides of the central axis 506 of the sealant region. The even distribution also avoids any sealant "tilting" problem. It is further noted that although Fig. 5 illustrate a continuous opening with a saw teeth pattern, this pattern does have to be used for the entire sealant region for encapsulating the display devices. For example, the corner portions of the sealant region may still use the conventional direct removal of the organic polymer layer with no patterns at all, while the center portion of each side of the sealant region or sealant frame may use the predetermined patterns.

[0027] Referring now to Figs. 6a to 6c, there are additional top views of the sealant region according to different examples of the disclosure for the sealant region for the encapsulation of the organic EL display devices. These top views are of lower magnification than the example shown by Fig. 5. These patterns for the sealant region illustrate how the sealant is placed along the perimeters of the EL display device 600. The shapes or the patterns of the sealant may be different from each other, such as the multiple parallel lines in Fig. 6a, the saw teeth shape in Fig. 6b, or the modified curved saw teeth shape in Fig. 6c, they share a common feature that when the sealant is placed in these openings, they are substantially evenly distributed on both sides of the central axis of the sealant region and the width of these openings is much smaller than the total width of the sealant region. The modified saw teeth pattern in Fig. 6c is to avoid sharp

angel formed by any two openings. In Fig. 6a, the two short openings formed in the corner region is also for balancing the distribution of the sealant. As shown, some patterns may be asymmetric in a particular local area such as the saw teeth pattern in Fig. 6b, but it is balanced as a whole along the center axis of either the horizontal or vertical sealant region. The balanced distribution of the sealant in the sealant region helps to reduce or eliminate problems caused by uneven cell gaps, thereby avoiding the so called around gap mura problem.

[0028] The sealing and encapsulation of organic EL display devices using the methods disclosed above in accordance with the present disclosure will result with less problems and concerns associated with the conventional sealing method. The use of improved method for forming the sealant region featuring the use of narrow gaps between the organic polymer areas, and enhance the adhesion between the two substrates.

[0029] The disclosed sealing method would be easily implemented into existing fabrication operations and processes with minimal impact to additional costs and required processes. The disclosed more reliable encapsulation seal will lead to higher production yields for the organic EL display devices, as well as higher integrity and longer operational life of the said devices. Such improvements will translate into significant cost improvements for a given production facility to

maintain highly competitive cost and output advantages over other manufacturers of similar product devices.

[0030] The above disclosure provides several examples for implementing the different features of the disclosure. Specific examples of components and processes are described to help clarify the disclosure. These are, of course, merely examples and are not intended to limit the scope of the disclosure from that described in the claims. For example, the organic polymer layer and passivation layer are specifically used as examples for illustration, it is understood that any variations of the material on the device substrate and the shield substrate may happen, and the disclosed sealing method can still be applied.

[0031] While the invention has been particularly shown and described with reference to the preferred embodiment thereof, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention, as set forth in the following claims.